Combining old and new stable isotope techniques to evaluate the impact of conservation tillage on soil organic carbon dynamics and stability

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Introduction

Soil organic matter is a major carbon pool and can play a significant role in carbon mitigation measures. It is also a crucial factor for several soil physical properties and a major nutrient source for crops. Soils can act as a carbon sink or source depending on land use and agricultural management practices. Some practices such as conservation tillage or no-tillage could increase the soil organic matter (SOM) stock in the (top) soil, but in the long term it remains to be seen if and how this SOM is stabilized.

In order to evaluate the sustainability and efficiency of soil carbon sequestration measures and the impact of different management and environmental factors, information on SOM stability and mean residence time (MRT) is required. However, this information on SOM stability and MRT is expensive to determine via radiocarbon dating, precluding a wide spread use of stability measurements in soil science. But alternative methods (Balesdent and Balabane, 1992; Conen et al., 2008), based on stable carbon and nitrogen isotopes, can provide this information at a fraction of the cost.

Objectives

In this paper, we look at the impact of long term conservation tillage on SOM distribution, dynamics and stability on four long term conservation tillage experiments in Belgium, using jointly old and new stable isotope and soil fractionation techniques.

Materials & Methods

Four long term agricultural fields were selected in Belgium. These sites have a maritime temperate climate with significant precipitation during all seasons and a warm summer. Two treatments were established since 2002 at each site, i.e. conventional tillage and conservation tillage. The crop rotation consisted of grain maize, winter wheat, potato, winter barley, winter rapeseed and sugar beet.

For each treatment and field, six replicates of 1m soil cores were sampled in the summer of 2014. The cores were divided in 8 different depth layers. Samples from depths of 0-5cm, 10-15cm, 40-60cm were divided into SOM and aggregate classes according to the fractionation schemes described by Conen et al. (2008) and Six et al. (2002). The samples from all depth layers, bulk soil and fractions, were analysed with an elemental analyser coupled to an IRMS for C and N content and their stable isotope ratios.

Results

The soil column sampling showed a significant increase in organic carbon content (%) in the 0-5cm soil layer of the conservation tillage treatment and a slight increase in the total carbon content down to 1m. This increase was mainly concentrated in the particulate organic matter and the protected micro-aggregate fractions. The relative stability of the SOM was calculated in three soil layers using a method, based on isotopic fractionation of ^{15}N developed by Conen et al. (2007). A clear increase in SOM relative stability could be seen with increasing depth and no difference was found between both treatments. The additional SOM in the top soil layer was as stable as the SOM in the conventional tillage treatment. Applying this approach to investigate SOM stability in different soil aggregate fractions, it corroborates the aggregate hierarchy theory. The organic matter in the occluded micro-aggregate and silt & clay fractions is less degraded than the SOM in the free micro-aggregate and silt & clay fractions.

Combining all measured parameters in a multivariate principle components analysis allowed discriminating between sampling depth, crop input and land use (till vs no till) systems. It was found that the $\delta^{13}C$ depth and aggregate profile differed significantly between both treatments. The Keeling plot approach is used on the bulk soil and aggregate fractions at different depths to estimate the contribution of the different crop residues and SOM turnover rates, as all fields have maize in their crop rotation.

Conclusion

Long term conservation tillage affects the carbon content of the top soil layer, but not the relative stability of the SOM. Changes in SOM aggregate distribution and changes in $\delta^{13}C$ depth profile can be observed between conservation and conventional tillage, suggesting changes in crop residue incorporation.

References

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